

APPENDIX A-1

CALCULATION METHODS

A-1: CALCULATION METHODS

A-1.1 GROUND TRANSPORTATION ENERGY CONSUMPTION

A-1.1.1 METHODOLOGY

Future ground sector energy demand was estimated as follows:

1. Determine the number of vehicles registered per county for the latest year data is available (Hawaii State Data Book). For this analysis, the most recent year for which data is available was 1992, which therefore becomes the “baseline” year.
2. Determine the number of vehicles in each of eight vehicle categories (Hawaii State Data Book).
3. Determine ground sector fuel use by county for the baseline year (Department of Taxation data).
4. Correct (3) by the amount of fuel “wasted” due to congestion losses. The calculation of fuel “wasted” due to congestion is patterned after the methodology of the Texas Transportation Institute (1994) and is shown in Figure A1-1. Since the inputs required for the congestion loss calculations were only available for Oahu, percentage of fuel “wasted” due to congestion on the neighbor islands was to be equal to the percentage of fuel “wasted” due to congestion on Oahu.
5. Determine average fuel use per vehicle per county, after deducting the amount of fuel “wasted” due to congestion losses: (4) divided by (1).
6. Determine projected annual increase in ground transportation activity per county (from county transportation plans).

Figure A1-1

CALCULATION OF ENERGY WASTED DUE TO CONGESTION

Definitions	
<u>Link Congestion Levels:</u>	
<i>Freeway</i>	
Uncongested:	Average Daily Traffic (ADT) per lane under 15,000
Moderate Congestion:	ADT per lane 15,000 - 17,500
Heavy Congestion:	ADT per lane 17,501 - 20,000
Severe Congestion:	ADT per lane over 20,000
<i>Arterial</i>	
Uncongested:	ADT per lane under 5,750
Moderate Congestion:	ADT per lane 5,750 - 7,000
Heavy Congestion:	ADT per lane 7,001 - 8,500
Severe Congestion:	ADT per lane over 8,500
Assumptions	
<u>Average Link Speeds:</u>	
<i>Freeway</i>	
Uncongested:	100 kilometers per hour (kph)
Moderate Congestion:	61 kph
Heavy Congestion:	53 kph
Severe Congestion:	48 kph
<i>Arterial</i>	
Uncongested:	60 kph
Moderate Congestion:	45 kph
Heavy Congestion:	40 kph
Severe Congestion:	37 kph

Figure A1-1

**CALCULATION OF ENERGY WASTED DUE TO CONGESTION
(Continued)**

<ul style="list-style-type: none">• Annualization factor - 250 days per year• 45 percent of Average Daily Traffic occurs during peak periods• Average daily arterial incident delay equals 1.1 times average daily recurring delay• Average daily freeway incident delay equals 1.8 times average daily recurring delay (specific to Honolulu)
Input Data
<p>Total daily Vehicle Miles of Travel (VMT) by facility type and congestion level:</p> <p>Freeway: Uncongested, Moderated Congestion, Heavy Congestion, Severe Congestion</p> <p>Arterial: Uncongested, Moderate Congestion, Heavy Congestion, Severe Congestion</p>
Calculations
<ul style="list-style-type: none">• Convert VMT by facility type and congestion level to Vehicle Kilometers of Travel (VKT)• Calculate Vehicle Hours of Travel (VHT) by facility type and congestion level: $\text{VHT} = \text{VKT} / \text{Average Speed (in kph)}$• Sum congested VHT by facility type (i.e., Moderate Congestion VHT + Heavy Congestion VHT = Severe Congestion VHT)• Sum congested VKT by facility type (i.e., Moderate Congestion VKT + Heavy Congestion VKT + Severe Congestion VKT)• Calculate peak period congested VHT by facility type: $\text{Peak period congested VHT} = \text{Daily congested VHT} * 0.45$• Calculate peak period congested VKT by facility type: $\text{Peak period congested VKT} = \text{Daily congested VKT} * 0.45$• Calculate, by facility type, the average peak period congested speed: $\text{Average congested speed} = \frac{\text{peak period congested VKT}}{\text{peak period congested VHT}}$

Figure A1-1

**CALCULATION OF ENERGY WASTED DUE TO CONGESTION
(Continued)**

- Calculate, by facility type, the VHT which would be spent by vehicles on congested facilities if those facilities operated at an uncongested speed:
$$\text{Peak period congested VHT, if uncongested} = \frac{\text{peak period congested VKT}}{\text{uncongested average speed}}$$
- Calculate, by facility type, average daily peak period recurring hours of delay:
$$\text{Recurring hours of delay} = \frac{\text{peak period congested VHT} - \text{peak period VHT, if uncongested}}{\text{VHT, if uncongested}}$$
- Calculate daily freeway hours of incident delay:
$$\text{Freeway incident hours of delay} = \text{freeway recurring hours of delay} * 1.8$$
- Calculate daily arterial hours of incident delay:
$$\text{Arterial incident hours of delay} = \text{arterial recurring hours of delay} * 1.1$$
- Calculate, by facility type, total daily hours of delay:
$$\text{Daily hours of delay} = \text{recurring hours of delay} + \text{incident hours of delay}$$
- Calculate, by facility type, average fuel economy of vehicles operating in congestion:
$$\text{Average fuel economy} = 3.74 + (0.11 * \text{average congested speed}) \times (\text{liters per kilometer})$$
- Calculate, by facility type, average daily fuel consumed during hours of delay:
$$\text{Daily fuel consumed during delay} = \frac{\text{daily hours of delay} * \text{average congested speed}}{\text{average fuel economy}}$$
- Calculate total daily fuel consumed during hours of delay:
$$\text{Daily fuel wasted} = \text{daily fuel consumed during freeway delay} + \text{daily fuel consumed during arterial delay}$$
- Calculate annual fuel wasted:
$$\text{Annual fuel wasted due to congestion} = 250 * \text{daily fuel wasted}$$
- Convert annual fuel wasted from liters to barrels

Sources: Parsons Brinckerhoff Quade & Douglas, Inc.
Texas Transportation Institute, 1994.

7. Determine number of vehicles per county for the future projection year. It is assumed that vehicle miles traveled (VMT) per year per vehicle stays constant:¹ On a per county basis, multiply (1) by (6) raised to the power of the difference in years between the projection year and 1992. This calculation increases the vehicle population at the rate of increase in transportation activity (essentially modeling future travel demand increases as an increase in the number of vehicles).
8. Determine future mix of vehicles based on historical trends (i.e. number of light trucks increasing at a faster rate).
9. Determine (as a percentage improvement from the baseline year) expected future vehicle efficiency through Corporate Average Fuel Efficiency (CAFE) standards (from Forecast of Transportation Energy Demand Through the Year 2010 (Argonne National Laboratory, 1991)).
10. Determine future level of fuel "wasted" due to congestion using the method shown in Figure A1-1.
11. Determine net level of future fuel consumption per county: discount (5) by (9), multiply by (7).
12. Determine total future fuel consumption: add (10) to (11).
13. Sum future county demands to obtain total state demand.

Based on this approach, total ground sector fuel demand would increase from 9.8 million gasoline-equivalent barrels (GEB) in 1992 to 10.3 million GEB in 1996, 10.6 million GEB in 1999, 10.9 million GEB in 2004, and 12.4 million GEB in 2014. These increases correspond to an annual rate of growth of about 1.05 percent between 1993 and 2014.

¹ This is consistent with the assumptions in use by the State Department of Transportation at the time their forecasts were prepared. The number of vehicles is used in these calculations essentially as a means of describing a relationship between transportation activity and fuels use, and when the number of vehicles is converted back to fuel demand, the assumption of constant VMT/vehicle becomes irrelevant due to the factors cancelling out of the equation. In general, the non-congestion fuel was determined as follows:

$$\begin{aligned}
 &(\text{VMT/VEH})_{\text{(current)}} \times \text{VEH}_{\text{(current)}} = \text{VMT}_{\text{(current)}} \\
 &\text{FUEL}_{\text{(current)}} \div \text{VEH}_{\text{(current)}} = (\text{FUEL/VEH})_{\text{(current)}} \\
 &(\text{VMT/VEH})_{\text{(current)}} \div (\text{FUEL/VEH})_{\text{(current)}} = \text{MPG}_{\text{(current)}} \\
 &\text{MPG}_{\text{(current)}} \times (\text{MPG CHANGE RATE})^{(\# \text{ years})} = \text{MPG}_{\text{(future)}} \\
 &\text{VMT}_{\text{(current)}} \times (\text{VMT CHANGE RATE})^{(\# \text{ years})} = \text{VMT}_{\text{(future)}} \\
 &(\text{VMT/VEH})_{\text{(future)}} \div \text{MPG}_{\text{(future)}} = (\text{FUEL/VEH})_{\text{(future)}} \\
 &\text{VMT}_{\text{(future)}} \div (\text{VMT/VEH})_{\text{(future)}} = \text{VEH}_{\text{(future)}} \\
 &(\text{FUEL/VEH})_{\text{(future)}} \times \text{VEH}_{\text{(future)}} = \text{FUEL}_{\text{(future)}}
 \end{aligned}$$

A-1.1.2 DISCUSSION

Some of the issues associated with this method include:

- A main “driver” of the projections are the average annual rates of increase in ground transportation activity projected for each county, as follows:
 - Kauai: 3.47 percent increase in daily vehicle trips (Kauai County Highway Planning Study - Final Report, October 1990);
 - Hawaii: 3.19 percent increase in daily traffic volumes (Island of Hawaii Long-Range Highway Plan Final Report, May 1991);
 - Maui: 3.93 percent increase in daily vehicle trips (Maui Long-Range Highway Planning Study - Island Wide Plan - Final Report, May 1991); and
 - Honolulu: 1.13 percent increase in vehicle miles traveled (VMT).²

Of the three travel parameters used above (daily vehicle trips, daily traffic volumes and VMT), VMT is most closely linked to energy demand. Because VMT estimates for the Neighbor Islands were not readily available, it was assumed that the percentage increases in the other travel parameters would be indicative of the increase in VMT on the Neighbor Islands.³

- Diesel and gasoline are commingled in the estimation. In future refinements, the calculation could be performed separately for gasoline and diesel if data on vehicle registrations by vehicle type by county were readily available, and assumptions were made about the relative use of gasoline and diesel by trucks.
- It is assumed that VMT per vehicle and trips per vehicle remain constant (see footnote 1).
- Percentage energy efficiency improvements expected for passenger vehicles were used to model efficiency improvements for the total state fleet because of the preponderance of passenger vehicles in the state fleet (see Figure 2-7). The assumed increase in energy efficiency turned out to have a major effect on future demand. In future refinements, efficiency improvements for each vehicle class could be considered separately. Also, since the Forecast of Transportation Energy Demand Through the Year 2010 (Argonne National Laboratory, 1991) only predicts fuel efficiency through 2010, it was assumed that 2010 energy efficiency levels applied through 2014.

² The Oahu Regional Transportation Plan (1991) contains projections based on three different scenarios. The three projections were combined to obtain the 1.13 percent increase.

³ It should be noted that all of the county plans from which the increases in transportation activity were obtained are currently being updated. Revised plans are expected in 1995.

A-1.1.3 COMPARISON OF THE PROJECTION WITH OTHER ANALYSES

The Hawaii Statewide Transportation Plan (STP) (Statewide Transportation Council and Department of Transportation, 1991) includes projections of DOT revenues from state fuel taxes on gasoline and diesel. These projections indicate an annual increase in fuel sold averaging 1.2 percent for the period between 1992 and 1997.⁴ This rate is higher than the 1.05 percent annual growth predicted by HES-5 between 1993 and 2014.

Forecasting a State-Specific Demand for Highway Fuels: The Case for Hawaii (PingSun Leung and Mary H. Vesenska, 1987) contains the following fuel consumption projections:

Highway Fuel Consumption Projection for 2000

Low Fuel Price	18 million barrels
Mid Fuel Price	11 million barrels
High Fuel Price	9 million barrels

This project forecasts fuel consumption of 10.6 million barrels for the year 1999. This projection is consistent with the projections listed above, falling quite close to the "mid fuel" price scenario.

A-1.2 AIR TRANSPORTATION ENERGY CONSUMPTION

A-1.2.1 METHODOLOGY

Future aviation sector energy demand was estimated as a function of passenger volumes and per capita fuel requirement according to the formula $F = B \cdot N$, where:

F = fuel consumption

B = per capita requirement (volume of fuel per passenger)

N = number of passengers

Interisland and overseas energy demands were calculated separately and then summed to obtain total aviation demand.

⁴ The STP is being revised in early 1995.

Data for B and N came from the following sources:

- N: Historical values were obtained from Airport Statistical Data (DOT), a data set including passenger volumes and cargo and mail tonnage distributed between “overseas” and “interisland” flights for all commercial airports in the state. The Hawaii Statewide Airport System Plan (Wilson Okamoto & Associates, Inc., 1990) provides forecasts of passenger volumes and cargo and mail tonnage apportioned between “interisland” and “overseas” flights for 1995, 2000, 2005, and 2010. Passenger volumes were used to drive the HES-5 projections. Aircraft operations (landings and departures) could have been used to drive the projections instead of passenger volumes, but the data on aircraft operations does not separate “interisland” and “overseas” operations. The Hawaii Statewide Airport System Plan (Wilson Okamoto & Associates, Inc., 1990) projects an annual average growth rate of passenger volumes of 2.29 percent. The forecasts were prepared in 1990 during a period of rapid growth in passenger and cargo volumes. Actual data in subsequent years do not reflect the growth in the aviation section projected by Wilson Okamoto & Associates, Inc. (1990).
- B: The interisland and overseas per capita fuel requirement is the ratio of fuel purchased to the number of interisland or outbound overseas passengers. An average of these ratios for the years 1989 to 1993 was used for the projections.

Total fuel consumption was obtained from the Department of Taxation data, which needed to be manipulated because interisland and overseas fuel purchases are combined. To separate the two fuel markets, since Act 65 distinguishes interisland and overseas purchases, the Department of Taxation total aviation purchase was allocated according to the split between interisland and overseas purchases as shown in the Act 65 data for each year. To allocate the Department of Taxation data for the years for which Act 65 data was not available (1991 and 1993), the average allocation from the Act 65 data for the years 1988, 1989, 1990 and 1992 was used (20 percent interisland; 80 percent overseas).

Since fuel efficiency is expected to improve through technology and operating practices,⁵ this effect was used to adjust the per capita fuel requirement. The Forecast of Transportation Energy Demand Through the Year 2010 (Argonne National Laboratory, 1991) expresses improvements in fuel efficiency as BTU's per revenue passenger mile. Argonne National Laboratory (ANL), the Federal Aviation Administration (FAA), and the Energy Information Administration (EIA) forecasted annual aviation efficiency improvements from 1985 to 2010 of 1.61 percent, 1.73 percent, and 1.88 percent, respectively. An average of these, 1.74 percent, was used in the HES-5 projections.

⁵ For further discussion, see Chapter 3.

A-1.2.2 COMPARISON WITH OTHER PROJECTIONS

A Study of the Aviation Fuels Industry in Hawaii for the Purpose of Energy Emergency Preparedness (Ed Noda & Associates, 1992) projects a demand of 21,754,000 barrels in 1995 and 31,645,500 barrels in 2010. HES-5 calculations project a demand of 16,877,333 barrels in 1995 and 20,507,875 barrels in 2010, approximately one quarter to one third less than Ed Noda & Associates' projections. Phase II Report on A Relocation Program and Development Plan for Petroleum-Oil-Lubricants (POL) Facilities in the Oahu Waterfront (William Brothers, 1992) presented a forecasted fuel demand in 2010 of 33 million barrels, around 13 million gallons more than the HES-5 calculations. These projects tend to overestimate demand because they are based on data available in 1992. In 1993, air transportation demand dropped significantly (refer to Figure 2-7).

A-1.3 MARINE TRANSPORTATION ENERGY CONSUMPTION

A-1.3.1 METHODOLOGY

Future marine sector energy demand was estimated as a function of projected cargo tonnage and fuel requirement per cargo ton according to the formula $F = B \cdot N$, where:

F = fuel consumption

B = gallons bunkered per cargo ton

N = cargo tonnage

Fuel consumption for interisland and outbound components of marine trade were calculated separately, and the energy demand of recreational boating was also included.

Data for B and N came from the following sources:

- B: Fuel consumption per cargo ton was calculated separately for interisland and overseas marine movements. Fuel consumption was obtained from Act 65 data, which partitions marine fuel use between interisland and overseas activities. The State Department of Transportation, Harbors Division has data on cargo tonnage partitioned between inbound and outbound, overseas and interisland movements for each commercial port in the state.

From 1983 to 1987, fuel utilization rates for both interisland and outbound overseas freight remained relatively stable. Between 1987 and 1989, however, the value for interisland movements decreased substantially, while the value for overseas movements climbed substantially. After 1989, these utilization rates became more stable. The average fuel utilizations for 1989 and 1990 were used for the projections.

Transportation Energy Demand Through the Year 2010 (Argonne National Laboratory, 1991) for essentially no change in marine sector fuel efficiency include:

- Engine replacements to increase fuel efficiency have already occurred;
 - Even though new engine technology improvements such as turbocompounding and rankine bottoming cycles have demonstrated fuel savings, these technologies have not been made commercially available; and
 - Since engine replacement cycles are typically quite long (30 years or more), the slow rate of engine turnover will delay improvements in marine fuel efficiency.
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- N: Harbors Division's statistics on cargo tonnage distinguish interisland and overseas movements. Between 1983 and 1990, interisland tonnage increased an annual rate of 6.2 percent and outbound overseas cargo tonnage grew at an annual rate of 1.2 percent. (Inbound overseas cargo is excluded from this analysis since it arrived with fuel bunkered elsewhere.)

There are no readily available statewide projections of cargo tonnage. It was assumed that the historical tonnage growth rate for interisland and overseas movements would continue, so that total tonnage is projected to increase from 10.7 million in 1990 to about 24.5 million in 2014, corresponding to annual growth of about 3.5 percent.

Information on recreational boating activity was obtained from Small Craft Mooring Facilities Utilization Report (DLNR, 1992) and Report of Undocumented Vessel Registration for 1991 (DOT). There were about 14,000 recreational vessels registered in the state between 1989 and 1991. Fuel use by recreational boats was about 84,000 barrels in 1991, yielding an average bunkering rate for recreational boats of about six barrels per boat per year. The impact of recreational boating on marine sector fuel demand is minimal.

A-1.3.2 COMPARISON TO PROJECTIONS BY OTHERS

Petroleum Facilities - Honolulu Waterfront Master Plan Technical Report (Jason Lembeck & Associates, 1989) projected a very small and relatively stable marine fuel demand from 1998 to 2010 for the state as a whole. For 2010, it only projected about a quarter of the total marine fuel demand predicted by this study.

A cargo forecast for the Island of Hawaii in 1990, Cargo Forecast for the Island of Hawaii (Manalytics, 1990), projected a rate of cargo increase of 2.93 percent from 1990 to 2010. This is relatively close to the marine fuel demand increase projected by this study, 2.37 percent from 1993 to 2014.